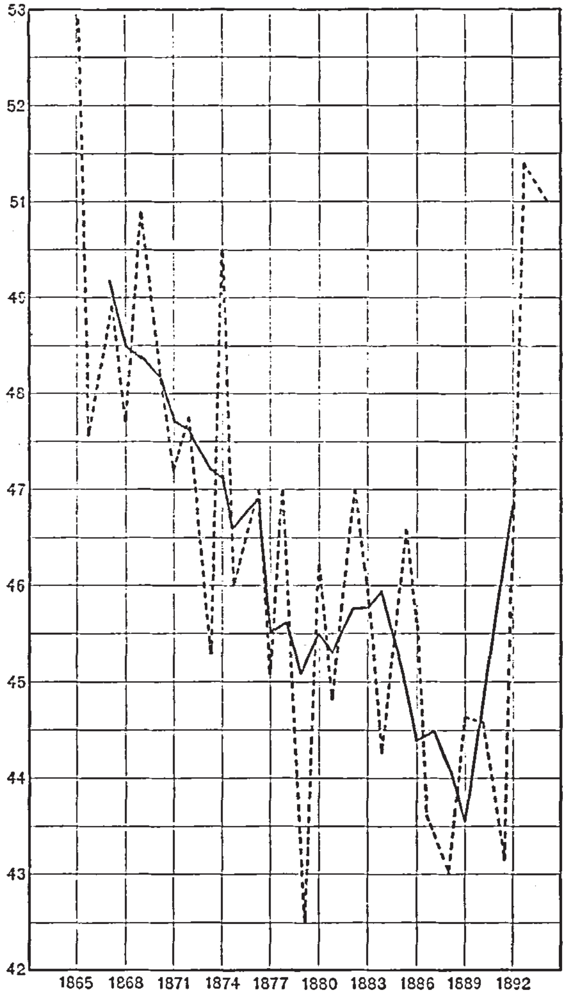
I am thankful to have had my attention called to the subject by Mr. Reade just upon the eve of departure for a few weeks among the glaciers of Umenak Bay, in Greenland. I will give special attention to the subject, and report upon my return in the autumn. G. Frederick Wright.

Oberlin, Ohio, June 23.

On a Recent Change in the Character of April.

The months are all, of course, continually changing in temperature, rainfall, &c. And, as a rule, those changes are not long in one direction; the curve of variation has many zig-zags. Yet, by methods of averaging, one may sometimes detect a gradual process of change extending through a good many years; we might compare it to the slope of an ocean-swell underlying the surface-ripples. The mean temperature of April at Greenwich is a noteworthy example of this.



Here are the values since 1865, and averaged in fives in a second column:—

	M.T. April.	Av.		M.T. April.	Av.		M.T. April.	Av.
	°	°		°	°		°	°
1865	52·9	—	1875	47·0	47·6	1885	47·6	46·1
66	48·6	—	76	48·0	47·9	86	46·6	45·4
67	49·9	50·2	77	46·1	46·5	87	44·2	45·5
68	48·7	49·5	78	48·0	46·6	88	43·5	45·1
69	50·9	49·4	79	43·5	46·1	89	45·7	44·6
70	49·2	49·2	80	47·2	46·5	90	45·6	45·2
71	48·2	48·7	81	45·8	46·3	91	44·2	46·8
72	48·8	48·6	82	48·0	46·7	92	46·9	47·8
73	46·3	48·2	83	47·0	46·7	93	51·4	—
74	50·5	48·1	84	45·3	46·9	94	51·0	—

Thus from a maximum of 50°·2 in 1867, the average went down, with some slight interruption at one point, to 44°·6 in 1889 (*i.e.* 5·6 degrees), the extreme actual values being 52°·9 in 1865 and 43°·5 in 1888 (difference 9·4 degrees). Last year and the present yield values in marked contrast to those just before, and a pronounced rise appears in the average curve.

The data for Paris and Geneva give results very similar, so that the process is not merely local. Thus the smoothed values for Geneva descend from 10°·6 C. in 1864 to 7°·9 in 1889.

A general, though less continuous, decline in the mean temperature of the entire spring (March to May), at Greenwich, may also be noticed.

I do not know whether any cause can be assigned for prolonged changes like these in April: some of your readers may be able to throw light on the matter.

The accompanying diagram illustrates the change referred to.

A. B. M.

The Deposition of Ova by "Asterina Gibbosa."

I recently brought back from Jersey three specimens of *Asterina gibbosa*, all of which deposited ova in the small aquaria in which they were kept. As it appeared evident that the ova exuded from the oral surface, two specimens were selected for experiment.

The first was placed with the oral surface uppermost in a small glass well, with just sufficient water to cover it. When examined about half an hour later, ova had exuded from a genital pore on the oral surface, and had floated up to the top. Had the opening been on the aboral surface, they would have been retained beneath the starfish.

The second specimen was then placed in a glass dish with the aboral surface uppermost. Sufficient water was added to allow the animal to be moved easily with a pair of forceps, but not enough to enable the tube-feet to act. Consequently ova, if deposited, could not float away. In this position it was left for about an hour. When turned, so as to bring the oral surface uppermost, it was seen that ova had exuded. The starfish was killed with the eggs still adhering.

The sexes of starfish are generally said to be separate. But in this case only three specimens were brought: all deposited ova, and in one small aquarium there are now young Asterinas.

Henry Scherren.

BIFILAR PENDULUM FOR MEASURING EARTH-TILTS.

Instruments designed for measuring movements of the earth's crust belong to two classes. The first consists of seismographs which register the amplitude and period of the rapid vibrations of earthquake-shocks, and by their records enable the velocity and acceleration of an earth-particle at any instant to be determined. The second class includes nadiranes and various forms of pendulums (such as the bifilar pendulum here described) which are, or should be, unaffected by vibrations of short period, and which indicate only slow tilts or bendings of the ground, showing the change of inclination at any spot, the rate at which it is taking place, and, if periodic, the length of its period. No part of the earth, so far as we know, is free from such movements. Every day, and every year, the surface of the ground at any spot tilts forward and backward through a small angle, perhaps not exceeding a small fraction of a second. Sometimes regular pulsations are observed, each a very few seconds or minutes in duration, and lasting, it may be, for hours; at other times the tilting is irregular and occasionally abrupt; but invariably it is so slight, and takes place so slowly, that without the aid of refined instruments it could never be perceived.

The report of the Earth Tremor Committee (British Assoc. Report, 1893, pp. 291–303), presented at the last meeting of the British Association, contains an account of a new bifilar pendulum designed by Mr. Horace Darwin, and of some of the first experiments made with it at Birmingham. This preliminary trial brought to light one or two slight defects which Mr. Darwin has endeavoured to remedy in the latest form of the instrument, of which a description is given in the present article.[1] The objects of the improvements are (1) to lessen the disturbing effects of the changes of temperature which take place in the neighbourhood of the instrument, and (2) to enable the angular value of the scale-divisions to be determined with greater ease and accuracy.

The chief novelty, both in the old and new forms of the bifilar pendulum, is the introduction of the double-suspension mirror for the purpose of magnifying the movements of the pendulum. This method was used by the Messrs. Darwin, at the suggestion of Lord Kelvin, in 1881, but it was also employed ten years earlier by M. Delaunay at the Paris Observatory.[2] In the latter case, however, the pendulum had a suspending wire 30 metres in length, and was installed in a deep pit, in which the effects of changes of temperature were so great that the successful working of the instrument was impossible.

The Double Suspension Mirror.—A small mirror, M (Fig. 1), is held in a light frame, from the upper edge of which there project two hooks or eyelet-holes, H H′. The mirror hangs by these on a fine silver wire or a silk thread, W, the ends P and P′ being attached to two supports very close to one another. In the figure these are shown in the same horizontal line; but this is not essential. All that is necessary is that the horizontal distance between them should be small.

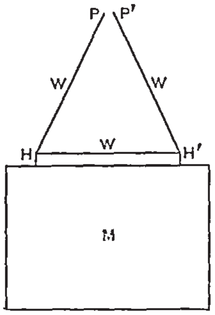


FIG. 1.

It is evident that the wire must always lie in a vertical plane passing through the centre of gravity of the mirror and its frame. If, then, while the point P′ remains fixed, the point P be slightly displaced at right angles to the plane of the wire, it follows that the mirror must turn through the same angle as the line P P′. To take a numerical illustration, let P P′ be one millimetre, and suppose the displacement of the point P to be one-thousandth of a millimetre, then the mirror will turn through an angle of 3′ 26″, a ray of light reflected by the mirror will turn through an angle of 6′ 52″, and consequently the image of the source of light upon a scale three metres distant will move through about six millimetres.

If the distance P P′ be diminished, the angle through which the mirror turns for a given displacement of the point P is increased, and the arrangement becomes more sensitive. In the position of the supports shown in Fig. 1, the thickness of the wire imposes a limit to the sensitiveness that may be attained. But if one support is placed above the other, the horizontal distance between them may be made as small as desired. It will be seen that this arrangement is the same as that in Mr. Darwin's pendulum, and therefore, in physical investigations in which the double-suspension mirror is used, the vertical distance between the points of support should be small, otherwise the accuracy of the results may be affected by the occurrence of earth-tilts.

If the support P were rigidly connected with the end of the pointer of a delicate balance, the plane of the mirror being perpendicular to that of the beam, the delicacy of the balance will, as Dr. Poynting has shown, be greatly increased. This is, in fact, the method used by him in his recent determination of the density of the earth.[1] Or, if the support P were attached to the bob of a pendulum, the movements of the latter might be magnified many hundred times, and the most minute earth-tilts be rendered visible. Here we have in principle the apparatus employed by Messrs. G. H. and H. Darwin to investigate the lunar disturbance of gravity. Their inquiry, as is well known, did not lead to the desired result, the movements due to the action of the moon being masked by the much larger ones produced by the continual tilting of the earth's surface.[2]

The Bifilar Pendulum.—The modified form of the bifilar pendulum was designed by Mr. Horace Darwin for the special purpose of observing and recording these earth-tilts and pulsations, the points in which it chiefly differs from that used in 1881 being that the mirror itself is the bob of the pendulum, and the whole instrument is much smaller. Fig. 4 is a sketch of the complete instrument, while Figs. 2 and 3 show the manner in which the mirror is suspended.

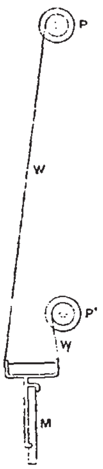


FIG. 2.

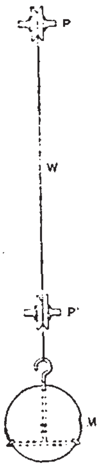


FIG. 3.

A circular mirror, M, about 20 mm. in diameter, hangs by two small hooks on a very fine silver wire, W.[3] The ends of this wire are fixed to two points, P P′, in the instrument, one of them very nearly vertically over the other. The distance between these points is about 180 mm. If the instrument be tilted about a horizontal line in the plane of the wire; the point P will be displaced relatively to P′ in the direction at right angles to that plane, and the mirror will in consequence turn round a vertical axis. At a short distance from the mirror is a lamp with a translucent disc in front, and the reflection of this disc in the mirror is observed by a fixed telescope. The stand supporting the lamp and disc is moved along a scale, and the position on the scale is read when the image of a wire in front of the disc coincides with the cross-wire of the telescope. The change of readings gives the tilt of the earth's surface about a line parallel to the plane of the wires supporting the mirror. Or, keeping the source of light fixed, a continuous record can be taken on a moving piece of photographic paper, and the value of the instrument will of course be greatly increased.

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[1] I am indebted to Mr. Darwin for notes about the changes made in his pendulum, as well as for the loan of the electros of Figs 2-4. The pendulum was made by the Cambridge Scientific Instrument Company One, of the improved form, has recently been placed in the Royal Observatory on Calton Hill, Edinburgh.

[2] C. Wolf, "Sur un appareil propre à l'étude des mouvements du sol." *Comptes Rendus*, vol. xcvii. 1883, pp. 229-230.

[1] *Phil. Trans.* 1891 A, pp. 572-574, 581-2: "The Mean Density of the Earth," pp. 78-80, 83-89.

[2] British Assoc. Report, 1881, pp. 93-126; 1882, pp. 95-119.

[3] The plane of the mirror is arranged at right angles to the plane of the suspending wire, in order that heat effects may as far as possible be eliminated. (See British Assoc. Report, 1893, pp. 300-301.)

If the instrument be tilted about a horizontal line at right angles to the plane of the suspending wire, the only effect is to alter the horizontal distance between the points of support, P P′, and therefore to change the sensitiveness. If the tilt be about any other horizontal line, it may be resolved into two components, one about a line parallel, and the other about a line perpendicular, to the plane of the wire. The first of these deflects the mirror, the second alters the sensitiveness; but this change of sensitiveness is nearly always very small, and may as a rule be neglected, because the displacement of P is always very small compared with the horizontal distance between P and P′. It will be obvious, however, from these remarks that the instrument is only capable of measuring tilts, or components of tilts, in one definite direction. For a complete knowledge of any given movement, it would be necessary to have a combination of two such instruments placed with the planes of their suspending wires at right angles to one another.

The body of the instrument consists of a copper tube fixed into a heavy gun-metal casting, containing a small chamber very little larger than the mirror, and covered in front by a glass window. Each end of the fine silver wire is attached to a small pulley, and the axles of the pulleys are gripped tightly so that the weight of the mirror is not sufficient to turn them. A strong copper frame carries the pulleys, and can be easily removed from the instrument, thus rendering possible the delicate operation of manipulating the silver wire. The bottom of the frame rests in a hollow cone inside the instrument just above the window; and the length of the silver wire is adjusted by turning the copper pulleys so that the mirror hangs in the small chamber facing the window. The top of the frame is pressed by a spring against the point of a micrometer screw, and can move only in a straight line in the direction of the screw, which is at right angles to the plane of the suspending wire.

A turn of the screw thus tilts the frame of the instrument about a line parallel to the plane of the wire. Knowing the dimensions of the frame and the pitch of the screw, the tilt caused by one turn, or given fraction of a turn, of the screw can be calculated, and the corresponding change of scale-reading determined. The screw is turned through a small angle by means of a lever (Fig. 4), and adjustable screw-stops are arranged at the bottom of the lever so as to allow it to move through only that amount which will make the frame tilt through an angle of two seconds. The lever is moved by a rocking-arm turned by means of two small bellows, into which air is forced by squeezing two india-rubber balls connected with them by long tubes.

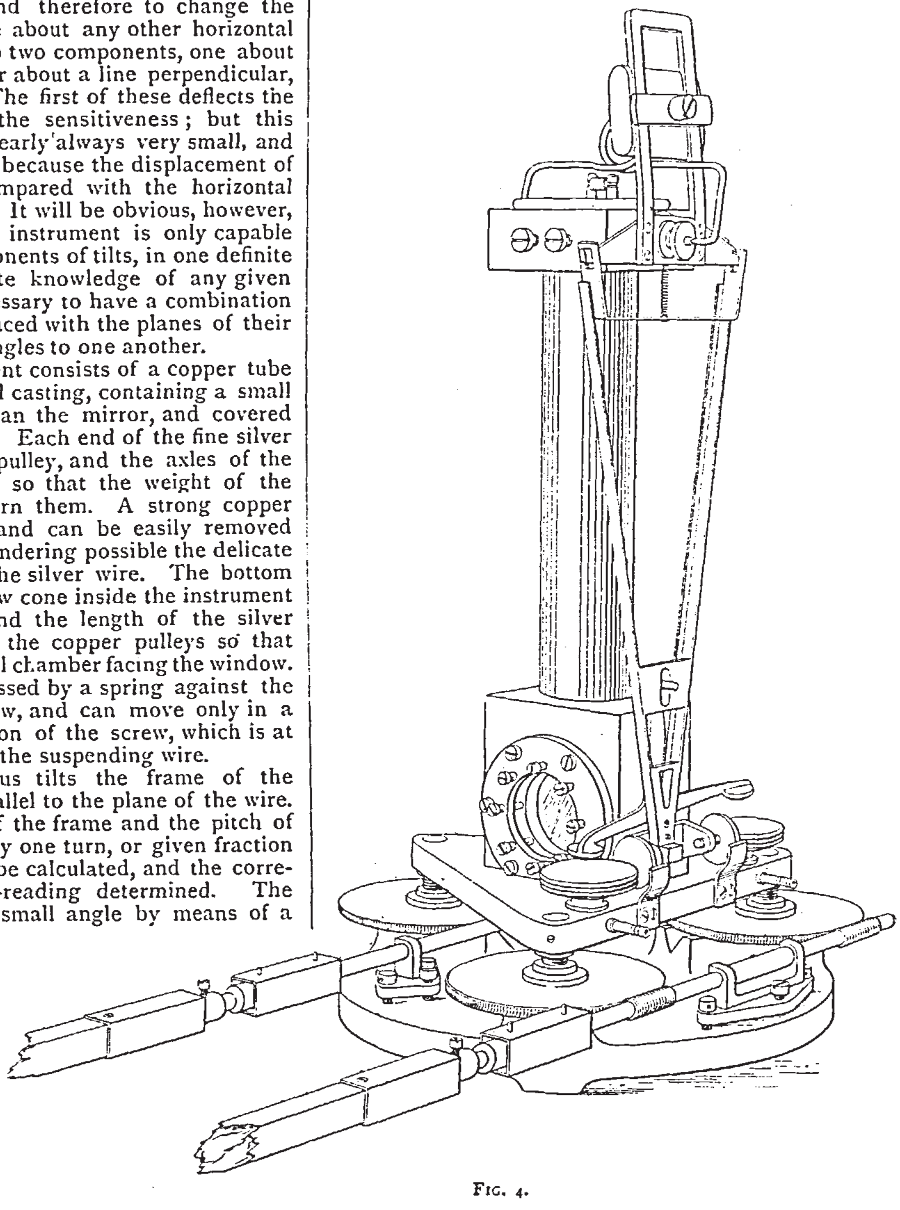

Fig. 4.

The instrument stands on three screw-feet, which are turned by two tangent-screws fixed to long rods. The ends of these rods are shown in Fig. 4. The tangent-screws are arranged so that turning one will tilt the instrument about an axis parallel to the plane of the suspending wire, and will therefore move the spot of light sideways, so that, when it has nearly left the photographic paper, it is easily brought back to the required position without approaching the instrument. Turning the other screw tilts the instrument about an axis perpendicular to the plane of the suspending wire, and this alters the sensitiveness.

When the ends of the silver wire have been fixed to the pulleys, and the frame, to which the latter are attached, has been inserted in the instrument, the copper tube is completely filled with paraffin oil. If the frame is tilted, the mirror then comes to rest very slowly, and rapid vibrations, like those caused by passing carts and trains, do not affect it. Thus the pendulum is designed, not so much for the study of earthquakes, as for the investigation of slow tilts and pulsations of the earth's crust, by whatever cause they may be produced.

Delicacy and Uses of the Bifilar Pendulum.—In the pendulum with which the preliminary experiments were made at Birmingham, the vertical distance between the points of support of the silver wire is one foot, while the horizontal distance between them is about $\frac{1}{250}$ of an inch. If the instrument be tilted through an angle of one second about a line parallel to the plane of the suspending wire the mirror turns through an angle of 49′, and the magnifying power of the instrument is therefore very nearly 3000. A scale is placed at a distance of ten feet, and 3·44 inches of this scale correspond to a tilt of one second. If the lamp be displaced by $\frac{1}{100}$ of an inch, the movement can be clearly perceived. It follows, therefore, that it is possible to observe with this pendulum a tilt of less than $\frac{1}{300}$ of a second, an angle less than that subtended by a line an inch long placed at a distance of a thousand miles.

It would seem, then, that the bifilar pendulum is admirably adapted for measuring the minute changes of level, which are perhaps the cause of some of the uneliminated errors in many astronomical and physical inquiries. Indeed, it may be hoped that the time is not far distant when a pendulum of this kind will be regarded as a part of the ordinary equipment of every great observatory. Again, the bendings of the earth's crust by changes of barometric pressure,[1] by the ebb and flow of the tides, &c., may be studied, as well as the long-period pulsations produced by violent earthquakes in almost any part of the world. It is not too much to expect, also, that in time we may be able to trace out and measure the slow secular movements of the earth's crust which, after the lapse of ages, become perceptible to the geologist; and that the vexed question of the origin of lake-basins may receive an answer that will remove this most debatable of subjects from the domain of controversy for ever.

C. DAVISON.

THE SPECTRUM OF OXYGEN IN HIGH TEMPERATURES.[2]

AT a previous meeting, I brought before the Academy a method, founded on the use of electricity, of bringing gases under pressure to a high temperature without heating sensibly the recipients which contain them.

Before rendering an account of the experiments already made on oxygen by means of this method, I shall mention first those which have preceded them, and in which temperatures not exceeding 300° have been realised by means of a line of gas jets playing directly on the tube containing the oxygen.

The arrangement was as follows:—A steel tube ten metres long, lined inside with red copper, and closed at its extremities by glass, according to our ordinary modes of closing, was placed in a trough containing a sand-bath. This trough was immediately warmed by a line of a hundred gas jets. The temperature of the tube was taken by means of thermometers metallically connected to the tube.

After having introduced the oxygen at the required pressure, and before the heating of the tube has begun, a good spectrum of a luminous light source is obtained, the beam being thrown along the tube in such a way that any change in the spectrum brought about by heating the gas is perceptible.

When the jets are lighted, the spectrum changes in proportion, as the temperature increases at the same time as the pressure. If the experiment is well conducted, the the pressure of the gas at the end, that is to say, when lights have been extinguished and the temperature has become what it was at first, returns to its original value. To obtain this result there must be no loss of gas during the experiment.

This loss of gas is caused principally by the lengthening of the pins that unite the pieces of steel which hold the glasses at the extremities of the tube. In order to prevent this lengthening, bands of brass have been placed between the heads of the pins and the disk, the length of which has been calculated to compensate by their expansion that of the pins. Thus the same degree of pressure is obtained at all temperatures.

The experiments have been made with varied pressures of oxygen. They show that from the ordinary temperature up to about 300° the bands and lines of the spectrum of absorption of oxygen do not undergo modification.

But quite a new feature is produced. A remarkable point is the very remarkable augmentation of transparency of the gaseous column with the increase of heat, a transparency revealed by a considerable augmentation of the brightness and the limits of the spectrum, above all on the side of the red. I shall have to return to the theoretical consequences of this important fact.

To ascend further in the scale of temperatures, it is necessary to make use of the platinum spiral tube rendered incandescent by the passage of the current.

I will not repeat the general arrangement of the experiment already described. The incandescence of the spiral is more difficult to obtain if the pressure of the gas is greater.

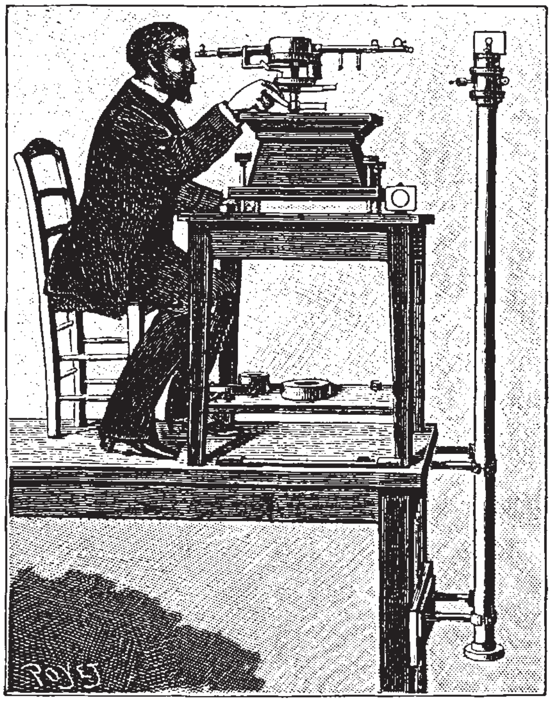

FIG. 1.—Experiments with a vertical tube and incandescent spiral.

The temperature to which the spiral is carried can be determined in different ways:—(1) The thermo-electric couple; (2) the observation of the increase of the pressure of the gas caused by the passage of the current; (3) and finally, the brightness and length of the spectrum given by the incandescent spiral, when it furnishes the light alone.

The experiment works thus:—

The tube being placed in a vertical position, the lamp, which must produce the beam to be analysed after its passage in the tube, is first regulated, and then the spectrum analysing apparatus is arranged. Pressure is then put on, and the constitution of the spectrum having been well observed, a current is made to pass, the power of which is proportional to the temperature which has to be obtained.

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[1] Such observations would gather additional interest if made in the neighbourhood of a great line of fault.

[2] A communication made by Dr. Janssen to the Paris Academy of Sciences. Translated from *La Nature*.